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Review on Effect of Partial Shading on Photovoltaic Array Configurations

Ms. Vaishnavi P. Deshpande, Dr. S. B. Bodkhe
[1]Department of Electrical Engineering Jhulelal Institute of Technology, Nagpur
vaishnavidhok11@gmail.com
[2]Department of Electrical Engineering Ramdeobaba College of Engg. & Management, Nagpur
bodkhesb@rknec.edu

ABSTRACT
Partially shaded conditions are common in all kinds of photovoltaic systems. The mismatch phenomenon of a Solar PV array, such as partial shade, not only affects the power generated by solar system, but also leads to safety and reliability problems. This paper gives a review of effect of partial shading on the photovoltaic array configurations.
Keywords— Energy sources, renewable energy system, partial shading, simulation, solar photovoltaic cell.

I. INTRODUCTION

Solar energy is the most effective, environmental friendly &economical source of energy. India receives solar energy equivalent to over 5,000 trillion kWh per year. The daily average solar energy incident over India varies from 4 -7 kWh per square meter per day depending upon the location. Energy supplied by the sun in one hour is equal to the amount of energy required by the human in one year. The solar energy can be utilized in two forms, firstly solar heating &solar electricity. The direct conversion of solar radiation into electricity is described as a photovoltaic (PV) energy conversion because it is based on the photovoltaic effect**.** Unfortunately, PV generation systems have two major problems: the conversion efficiency of electric power generation is low (in general less than 17%, especially under low irradiation conditions), and the amount of electric power generated by solar arrays changes continuously with weather conditions [1,2].

Under uniform irradiance condition, maximum power point tracking (MPPT) controller is used for extracting the maximum power from the solar PV module and transferring that power to the load. A dc/dc converter (step up/step down) serves the purpose of transferring maximum power from the solar PV module to the load. However, in many applications the solar photovoltaic arrays might be illuminated non-uniformly .The cause of non-uniform irradiation may be shadows clouds, trees, shadow of one solar array on another etc. Partial shadows of solar PV array can cause undesired effects such as:

- The power actually generated from the solar PV array is much less than designed.
- The local hot spot in the shaded part of the solar PV array can damage the solar cells[3]

II. LITERATURE SURVEY

(Quaschning and Hanitsch, 1996) introduced the problem of partial shading. A number of series/parallel connected PV modules form a solar array for a desired voltage and current level. Performance of a series connected string of solar cells gets adversely affected if all its cells are not equally illuminated (partially shaded). In a solar array shadow may fall over some of its cells due to tree leaves falling over it, birds or bird litters on the array, shade of a neighboring construction etc. In a series connected string of cells, all the cells carry the same current. A few cells
under shade produce less photon current but these cells are also forced to carry the same current as the other fully illuminated cells. The shaded cells may get reverse biased, acting as loads, draining power from fully illuminated cells. If the system is not appropriately protected, hot-spot problem can arise, the system gets irreversibly damaged.[4]

The study of partial shading of modules a key issue. (Herrmann et al, 1997; Kaushika and Gautam, 2003; Klenk et al, 2002;Woyte et al, 2003) discuss the difficulties in the of study of physical solar PV module i.e. the field testing is costly, time consuming and depends heavily on the prevailing weather condition. Also it is difficult to maintain the same shade under varying numbers of shaded and fully illuminated cells throughout the experiment.

So they focus on simulation study with the help of a computer model.[5,6]

(Hans.S.Rauschenbach et al.,1971; M.C.Alonso et al., 2006; M.C.Alonso-Garcia, 2007; Engin Karatepe et al., 2007)focuses on the effect of partial shading in reducing the output power of the solar PV array. The power dissipated by the shaded cells affects the array life and utilization of the array.[7]

(Ramaprabha &Badrinath,2009) focuses on harmful effect of partial shading on series & parallel connection by considering power dissipation & uses bypass diodes in antiparallel to partially solve the problem of power reduction due to partial shadow.[8]

(M. S. Swaleh and M. A. Green,1982) uses bypass diodes to connect across shadowed cells to pass the full amount of current thus preventing damage to the solar cell. This method usually requires a great number of bypass diodes that are integrated in the solar arrays. The production of solar arrays with bypass diodes is more costly. Additional to this the power losses of solar PV arrays are not completely prevented because there are additional power losses when the current passes though the bypass diodes. [9]

(W. Xiao, N. Ozog, and W. G. Dunford) proposes that in a large system if each submodule is connected with its separate MPPT dc to dc converter then efficiency of solar cell increases but it adds to the cost.[10]

Partial shading causes many local maximas, so it becomes more difficult to get optimum power output. (Smita &pankaj, 2012) developed a matlab program providing the global maximum power point to increase the power output [11]. Alternatively, the maximum output DC power can be improved if the connection of the SPV modules can be reconfigured. Traditionally, fixed solar PV arrays have hardwired interconnections between their solar cells. These connections are not changed after installation. The idea of reconfiguring the connection of solar cells to achieve a certain electrical condition was developed by Gruber & also had a patent for a Self-Reconfiguring Solar Cell Array, while Craig had a patent for a Solar Array Switching Unit (SASU). Similarly an Electronic Array Reconfiguration Controller, this work was supported in part by the Philippine Department of Science and Technology under the Engineering Research and Development for Technology.

A switching algorithm was developed in (G. Velasco, J. Negroni, F. Guinjoan, and R. Pique, 2005) using the idea of PV array reconfiguration (M. A. El-Shibini and H. H. Rakha, 1989) continuously rearrange solar cells in series and parallel connections to facilitate the PV system to work as a constant power source, even in different operating conditions (i.e., insolation, temperature, loads, etc.).[12]

Research study in (Y. Auttawaitkul, B. Pungsiri, K. Chammongthai, and M. Okuda, 1998) developed method to reconfigure solar cells to improve power output in shaded conditions.

(R. A. Sherif and K. S. Boutros) focused on building reconfigurable array but this approach had unrealistic no of switches.(Dzung Nguyen and Brad Lehman,2008) proposed adaptive reconfiguration of solar array with reduced no of switches & sensors. They developed new method for reconfiguration of solar PV arrays in real time under shadow conditions. Solar cells from a (smaller) solar adaptive bank get connected to the (larger) fixed part of the solar array. The MPP of the whole array was tracked by a single common MPP tracker. In this approach they reconfigured only a small percentage of the solar arrays so no of switches reduced &control algorithm becomes simplified. In the uniform illumination conditions, all adaptive solar cells equally get connected to all rows of the fixed part of the solar PV array. In nonuniform illumination conditions, the number of the adaptive solar cells connected to the shaded submodules depends on the shaded area of the submodules. The reconfiguration is executed through the proposed switching matrix. They have used a Simple control decision algorithms to determine when and how to open and close switches between the fixed part and adaptive bank of the solar PV array. The algorithms based on model prediction implemented by microcontrollers or digital signal processors.[14,15]

To reconfigure, Several SPVA configurations have been proposed. They are series, parallel, series-parallel (SP) total cross-tied (TCT) bridge-linked (BL) and Honey-comb (HC) configurations(Y. J. Wang and P. C. Hsu,2011) The solar array size & its configuration both significantly affects DC power output, so it is very important to study, and understand the effects of shading on SPV arrays, So (Patel and Agarwal,2011) have proposed a MATLAB based-simulator cum learning tool to understand the characteristics of a large SPV array.

In (Ramprabha & Mathur, 2012) developed a generalized program for comparison of different SPVA configurations in Matlab programming. Analyzing the various configurations for different random shading patterns for varied sizes, they observed that in most cases TCT gave a higher amount of power for symmetrical array size and HC configuration for asymmetrical array sizes.[16]

(Lew Andrew R Tria Miguel T. Escoto, Jr. Carl Michael F. Odulio, 2009) developed a photovoltaic array reconfiguration algorithm to maximize the power that an array can provide to a load. The algorithm reconfigures the array such that each element of the array is operated at its maximum power point. They have also designed switch topology to implement the algorithm (worked on two parameters i.e. array loaded voltage and temperature) using the minimum number of switches. [18]

The usual reconfiguration algorithm is connecting the solar cells after checking whether partial shade happened. It will make the photovoltaic cells compensate overly or defectively. This method is inefficient. (Ze Cheng, Zhichao Pang, Yanli Liu and Peng Xue, 2010) suggests the shading degree model-based fuzzy control algorithm to resolves this problem. Since the cells in the adaptive bank might be fully or partly shaded, the number of cells in the adaptive banks is limited. According to the fuzzy rules, the cells are compensated for the submodules which are shaded seriously first. The cells with the most irradiance of the adaptive bank are connected to the most shaded submodule with the least irradiance. The power losses of the submodules are different, so it needs to find the right amount of cells to compensate in the adaptive bank. It reduces the waste of resources.[22]

(Yanli Liu, Zhichao Pang, Ze Cheng, 2009) introduces new techniqsa When the PV array is partially shaded, due to the complexity and changes of shading conditions, the shading area and irradiation of each submodule (one row of the TCT PV array is defined as a submodule) of PV arrays is different, so it is difficult to determine the number of cells in the adaptive bank which are required to compensate the shaded submodules. This paper proposes an adaptive solar PV array using shading degree model-based reconfiguration algorithm, by using "shading degree" to show the power loss of each submodule. In this paper, the size of decline in the photo-generated current of each submodule is defined as "shading degree". [22]

AN ADAPTIVE RECONFIGURATION METHOD

From literature survey it is clear that in order to increase the power output under shadow condition array reconfiguration is widely used. All researches focus on the development of an adaptable solar array that is able to optimize power output. In this method solar array is divided into two parts.

1) Fixed solar array (larger array)
2) Adaptive Solar array

Solar adaptive array get connected to the (larger) fixed part of the solar array. The MPP of the whole array is tracked by a single common MPP tracker (MPPT). Since only a small percentage of the solar arrays are reconfigurable, fewer switches and simplified control algorithms are possible. In the uniform illumination conditions, all these adaptive solar cells will be equally connected to all rows of the fixed part of the solar PV array. In non uniform illumination conditions, the number of the adaptive solar cells connected to the shaded submodules depends on the shaded area of the submodules. The reconfiguration is executed through the switching matrix. The switching matrix is programmed to minimize the effect of partial shading. Simple control decision algorithms are presented to determine when and how to open and close switches between the fixed part and adaptive bank of the solar PV array. The algorithms rely on predictions that can be implemented in real time by microcontrollers or digital signal processors [14.15]

III. CONCLUSION

This paper has carried out the study of most relevant papers on the MPPT & partial shading. As a result of this review, it is found that array reconfiguration method has been most frequently analyzed. After this review it is found that lot of switches are used which leads to maximise the cost of overall system. Very less work has been published to minimize the number of switches in the switching matrix. If number of switches will reduce it will ultimately reduce the cost of energy. Hence it is essential to work in this area of research.

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